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Exxon's Edward David critiques current and past science policies Page 9

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Catalysts

Steady growth ahead

Page 19

Cover: Catalyst feed material exits from the primary heat circuit at Engelhard's Mcintyre, Ga., plant

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CHEMICAL & ENGINEERING
NEWS
DECEMBER 5, 1983

News of the Week

■ **Presidential science adviser Keyworth names deputy director, five assistant directors for White House OSTP.** **Page 6**

■ **U.S. chemical industry spending for R&D in 1984 will increase 11% over the 1983 level, NSF survey indicates.** **Page 7**

■ **Current space shuttle mission carries heaviest scientific payload to date.** **Page 7**

■ **Harvard University receives patent rights to genetic engineering process to make proteins.** **Page 7**

Business

Catalysts constitute a profitable industry and products for the petroleum refining, automotive, and chemical areas are expected to enjoy a combined 3% annual growth through 1987. **Page 19**

Government

In its final session, Congress passed agency appropriation bills, but postponed bills on natural gas prices, pesticides. **Page 32**

Science

Spacelab 1 aboard the space shuttle will be used to conduct more than 70 experiments in five scientific research areas. **Page 40**

Technology

Administration's expansion of the U.S. Exclusive Economic Zone will aid prospective miners if economics are favorable. **Page 47**

Books

The evolution of AIChE and its contributions are traced in "75 Years of Progress—a History of the American Institute of Chemical Engineers 1908–1983" by Terry S. Reynolds. **Page 56**

Letters 4

Concentrates
Business 16
Government 28
Science/Technology 38

The Departments
New Products 55
ACS News 63
People 65
Newscripts 86

News Focus

Edward E. David, former science adviser to President Nixon, says current Administration is getting effective advice, discusses federal role in innovation. **Page 9**

Catalysts: a Chemical Market Poised for Growth

Moving up steadily from sales base of $1.3 billion, catalysts are good business but demand heavy outlays for development and service

Stephen C. Stinson, C&EN New York

Continued recovery of the U.S. economy is bringing renewed, if sometimes uneven, growth to catalysts used by various industries. Catalyst use in the U.S. could top 4.7 billion lb this year, worth about $1.3 billion, up 3% from last year.

Among the three principal industries that use catalysts, petroleum refining is the largest. It might consume 4% more catalysts this year than in 1982, bringing the total to 4.5 billion lb, valued at $530 million. Of this, however, 4.1 billion lb will be low-price, commodity sulfuric and hydrofluoric acid alkylation catalysts, some on solid support and some not, amounting to only $165 million. The chemical industry may raise its use 4% to 210 million lb, valued at $485 million. Automotive and industrial emission control catalysts could reach a value of $325 million, down 3% from 1982.

Overall, the catalyst business is a good one to be in, according to analyst Bruce W. Deckman of Strategic Analysis, Reading, Pa., business consultants to the chemical, mineral, metal, and allied industries. One reason he cites is its large size, well over $1 billion. A second reason is the relatively modest but steady 3% annual growth he predicts for catalyst volumes through 1987. Third, catalysts are very profitable products in general, he says, whose development is based on sophisticated technology and whose marketing depends on skilled technical service. Thus, firms who can acquire such expertise find catalysts attractive specialties to enter.

Indeed, acquisition of existing suppliers or personnel is the preferred route into the business, Deckman says, because of technological requirements as well as the close personal contacts and track record of success elsewhere needed to sell to conservative customers. One recent newcomer, Katalistiks of Baltimore, seems to prove the rule. Originally founded in Amsterdam as a joint venture among Catalyst Recovery International of Baltimore, EKA of Göteburg, Sweden, and English China Clays of St. Austell, England, the firm established a U.S. subsidiary in 1982. Katalistiks specializes in fluid cracking catalysts for petroleum refining. The company's first move was to hire many management, research, technical service, and sales people from competitors. The firm depended on imports from its Delfzijl, the Netherlands, plant for a year. Then, a 130 million lb-per-year plant opened in Savannah, Ga., in June 1983.

Monolithic catalyst made by Engelhard can remove industrial exhaust contaminants and paint fumes

A second new organization, Harshaw/Filtrol Partnership, headquartered in Cleveland, is a joint venture founded in November by combination of Kaiser Aluminum & Chemical's Filtrol Corp. and Gulf Oil's Harshaw Chemical Corp. Filtrol made catalytic cracking, hydrotreating, and hydrocracking catalysts. Harshaw produced hydrotreating and hydrocracking catalysts, as well as those for chemical production. The move satisfied a desire by Gulf managers to get out of specialty chemicals and concentrate on their commodity chemicals and oil business.

Twenty-six firms are major suppliers of catalysts

Supplier	Petroleum refining	Chemical processes	Emission control
Abbott Laboratories		●	
Activated Metals		●	
Air Products	●	● ●	
Akzo Chemie America Catalyst division	●		
Noury Chemical		●	
American Cyanamid	● ●	◌	
Calsicat[a]		● ● ●	
Catalyst Resources[b]		●	
Davison[c]	◌	● ◌ ●	
Engelhard	◌	◌ ●	●
Ethyl		●	
Halcon		◌	
Haldor Topsoe		◌ ●	
Harshaw/Filtrol[d]	◌ ● ●	◌ ●	
Johnson Matthey		◌ ●	●
Katalco[e]	●	◌ ●	
Katalistiks	◌		
Lucidol[f]		●	
M&T Chemicals[g]		●	
Monsanto		◌	
Shell Chemical	● ●	◌ ●	
Stauffer Chemical	●	● ◌	
Texas Alkyls[h]		●	
UOP[i]	● ●	●	●
Union Carbide		● ◌	
United Catalysts		◌ ● ● ◌ ● ●	
Witco Chemical Organics division		●	
Pearsall Chemical		●	
U.S. Peroxygen		●	

Key:

- ◌ = Catalytic cracking
- ● = Hydrotreating
- ● = Alkylation
- ● = Hydrocracking
- ◌ = Catalytic reforming
- ● = Polymerization
- ◌ = Oxidation, ammoxidation, and oxychlorination
- ● = Organic synthesis
- ● = Hydrogenation
- ● = Steam reforming
- ● = Ammonia and methanol synthesis
- ● = Dehydrogenation

a Division of Mallinckrodt. b Division of Phillips Chemical. c Division of W. R. Grace. d Joint venture of Gulf Oil and Kaiser Aluminum & Chemical. e Joint venture of Nalco Chemical and Imperial Chemical Industries. f Division of Pennwalt. g Subsidiary of Elf-Aquitaine. h Joint venture of Hercules and Stauffer Chemical. i Subsidiary of Signal. **Source:** Strategic Analysis

Kaiser has six years to decide whether it will buy out Gulf's share.

But for all the attractions of catalysts, Deckman of Strategic Analysis advises caution to those who would enter the business. First, catalysts are cyclical, depending as they do on levels of activity in the oil, chemical, and automotive industries. Also, changes in energy costs and technological developments have definite impacts on specific products. And catalyst producers are susceptible to occasional materials shortages and wide price swings in raw materials.

For example, according to Bureau of Mines reports, disorders in Zaire in 1978 led to disruption of copper mining there, of which the catalytically important metal cobalt is a by-product. Cobalt had not been mined in the U.S. since 1971. A U.S. cobalt refiner put customers on 70% allocation for two years. During the period, prices rocketed to $25 per lb from $6.40, with spot sales at $45.

On the other hand, rhenium is an example of a raw material whose price and supply have depended on technological development and government regulations. Platinum and rhenium on a support become a so-called bimetallic reforming catalyst that can allow far more production than platinum used alone—the practice before bimetallics were developed. Catalytic reforming is a process that increases amounts of octane-improving aromatics and olefins in a hydrocarbon stream. Bimetallic catalysts had been under study at refineries all through the 1970s. But when the full effects of the phaseout of lead additives in gasoline began to take hold in 1979, that plus the temporary gas shortages of that year drove refiners to order large amounts of bimetallic catalyst. The price of rhenium soared to $2500 per lb from $350 by mid-1980. Thereafter, economic recession, imports, and increased efforts of U.S. molybdenite roasters to recover by-product rhenium restored the supply/demand balance.

But if such external factors as government regulations can give catalyst producers raw material supply and price headaches, they also can give birth to whole new profitable

businesses. The Clean Air Act of 1970 gave birth to the automotive emission control catalyst business, starting with the 1975 model year. Today, catalyst sales to the U.S. auto industry alone account for one fourth of catalyst industry sales. Principal suppliers of this catalyst type are American Cyanamid, the Davison division of W. R. Grace & Co., Engelhard Corp., Johnson Matthey, and UOP.

Through the years, there has been a slow evolution away from pelleted automotive catalysts in the direction of monolithic types, originally invented by Engelhard's Carl D. Keith, who is now executive vice president. Monoliths are blocks of porous ceramic with honeycomb structures, coated on the interiors with a wash of precious metal solution. This type finds increasing favor because its greater surface area per pound requires only a 2-lb block, in contrast with the 7 to 8 lb of alumina pellets needed to accomplish the same effect in a catalytic converter. This has saved space, weight, and cost of precious metals, especially since 1978, as emissions standards tightened and pellet-containing converters got larger in the face of a trend toward smaller cars.

American Cyanamid and Davison sell pellets, which General Motors still may use in less than half of its production. Engelhard supplies both pellets and monolith. Johnson Matthey makes only monolith.

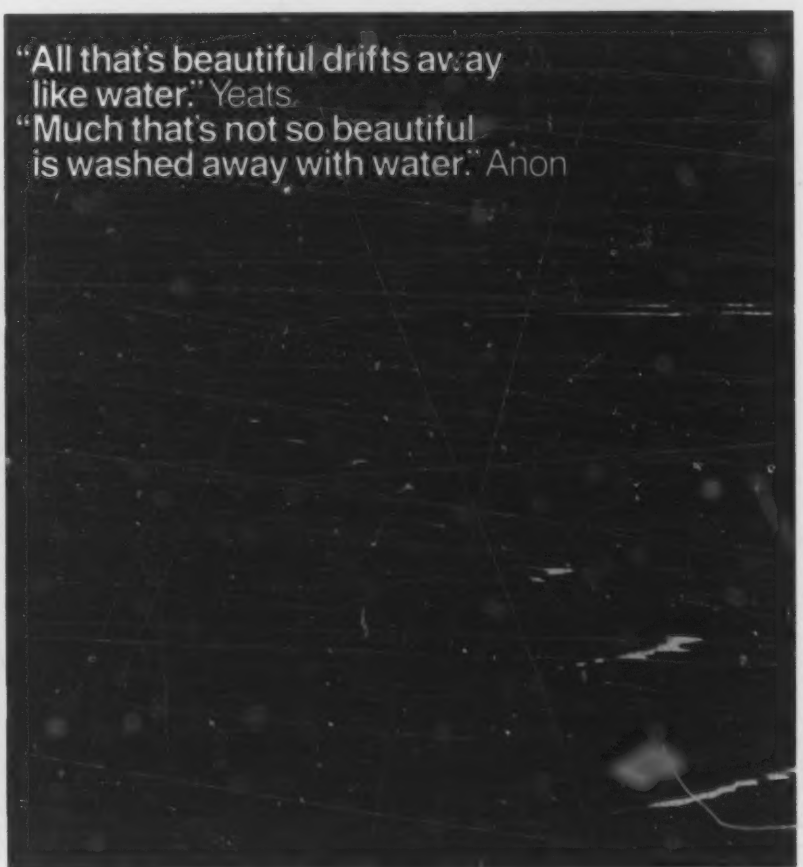
But pellet makers have not been idle. One of those confident of reversing the trend is Don McCulloch, who is both technical director of Cyanamid's catalyst department (refinery and chemical production catalysts) and general manager of Catalyst Co. (automotive catalysts), a joint venture with Japan Catalytic. Catalyst Co. has developed a new, less costly process for pellet production that involves fewer impregnation, drying, and calcination steps. These new catalysts are in trial at General Motors, where truck engine converters are among those that may not need space and weight savings of monoliths.

In addition to a trend toward monolithic automotive catalysts, increasingly stringent nitrogen oxide emission regulations have sparked a move toward dual-bed converters. In this system, a platinum-rhodium catalyst processes an oxygen-lean exhaust gas to reduce nitrogen oxides to nitrogen. After air injection, the gas passes to a conventional platinum-palladium catalyst for oxidation of carbon monoxide and hydrocarbons.

Development of dual-bed converters again was pioneered by Keith of Engelhard, whose work won Engelhard awards from the U.S. Council on Environmental Quality and the United Nations. Such converters in use today may be either two units in sequence or one unit with two catalyst beds within it. The next step in catalytic converters may be a return to a single unit with a single catalyst type, Keith says, with a resulting cost savings. He notes that this type is already available in some European imports. Keith cautions that introduction of single-catalyst converters by U.S. auto makers will depend on catalyst research and improvement of controls by car makers. The eventual catalyst for this next generation may be platinum-rhodium, platinum-palladium-rhodium, or some formulation that includes other metals, he says.

The rise in consumption of precious metals for the new application of auto catalytic converters has given birth to a new industry that recovers those metals. Recovery of precious metals from petroleum refining and chemical production catalysts has long been the norm. Recovery from converters poses special problems of rounding up large numbers of scrapped units and separating the relatively small amounts of precious metals they contain.

Two firms that have solved these problems are Gemini Industries, Santa Ana, Calif., and Johnson Matthey. J. P. Rosso, assistant to the president at Gemini, says that his company began missionary work among automobile junkyards by giv-



CIRCLE 6 ON READER SERVICE CARD

Chemical industry uses wide variety of catalyst types

Selected processes	Products	Major catalysts used
POLYMERIZATION		
Ethylene, propylene	High-density polyethylene, polypropylene	Trialkylaluminums and titanium(IV) halides (Ziegler-Natta types)
Ethylene, vinyl chloride, styrene	Low-density polyethylene, polyvinyl chloride, polystyrene	Organic peroxides
SYNTHESIS GAS		
Steam hydrocarbon reforming	Hydrogen and carbon monoxide	Nickel on alumina with potassium oxide promoter
Ammonia synthesis	Ammonia	Ferric, aluminum, and calcium oxide with potassium oxide promoter
Methanol synthesis	Methanol	Combinations of aluminum, chromium(III), cupric and/or zinc oxides
Olefins	Aldehydes	Cobalt, rhodium, or ruthenium complexes with carbon monoxide, amines, or phosphines
Acetic acid	Acetic anhydride	Iodine and complexes of rhodium with carbon monoxide and phosphines
ALKYLATION		
Benzene	Cumene	Phosphoric acid on silica
Benzene	Detergent alkylates	Aluminum chloride, fluoboric acid, or hydrogen fluoride
Benzene	Ethylbenzene	Alumina and silica or phosphoric acid on silica
HYDROGENATION		
Benzene	Cyclohexane	Nickel or platinum on alumina with lithium oxide promoter
DEHYDROGENATION		
Butane	Butadiene	Chromium(III) and aluminum oxides
Butene	Butadiene	Calcium and nickel phosphates; ferric and aluminum oxides; or ferric and chromium(III) oxides
Ethylbenzene	Styrene	Ferric oxide with chromium(III) and potassium oxide promoters
Petroleum hydrocarbons	Benzene, toluene, and xylenes	Platinum and rhenium on silica and alumina
OXIDATION		
Ammonia	Nitric acid	Platinum-rhodium gauze
Ethylene	Ethylene oxide	Silver on alumina with cesium oxide promoter
Methanol	Formaldehyde	Copper or silver, as gauze or on support; or ferric and molybdic oxides
Propylene	Propylene oxide	Molybdenum, vanadium, or titanium naphthenates
Sulfur dioxide	Sulfur trioxide	Vanadium pentoxide
AMMOXIDATION		
Methane	Hydrogen cyanide	Platinum-rhodium, as gauze or on support; or platinum, ruthenium, or aluminum on ceramic support
Propylene	Acrylonitrile	Uranyl antimonate
OXYCHLORINATION		
Ethylene	Ethylene dichloride	Cupric chloride on support

Sources: Charles H. Kline & Co., SRI International, and K. Weissermel & H.-J. Arpe, "Industrial Organic Chemistry"

ing talks to and advertising in publications of the Automotive Dismantlers & Recyclers Association and the National Association of Recycling Industries. Auto scrappers already were required by law to remove gas tanks before junking, and Gemini spokesmen pointed out to them that it would take only 15 seconds more to cut out the converters. In addition, Rosso says, when the price of platinum hit $985 per troy ounce in 1980, middlemen sprang up all over the U.S. to organize converter collection in their areas, break them up in regional warehouses, and ship the drummed contents to Gemini. Sale prices for converters reached $12 at that time, but have since subsided to $4.00, owing to lower platinum prices. Rosso says that it takes a platinum price of $400 to $450 per ounce to encourage large-scale converter shipments to his firm. Gemini recovers palladium and rhodium as well as platinum and accepts monolith as well as pellet supports.

Among all catalyst makers, three that produce for the auto industry—Cyanamid, Davison, and Engelhard—are the only ones that span the two other major user industries: chemicals and petroleum. Such specialization also is typical for catalyst producers who aim at a target industry, Deckman of Strategic Analysis points out. In the oil industry, for example, Cyanamid supplies catalysts only for hydrotreating, hydrocracking, and reforming, Davison for cracking, and Engelhard for cracking and reforming. This kind of specialization also occurs by process. Most needs for catalytic cracking, reforming, and hydrocracking are served by only four firms, for example, and the four are not the same for each process. Just six companies account for most sales to hydrotreating, the fastest-growing refining catalyst market.

Hydrotreating and the catalysts it uses will grow 5% annually at U.S. refineries through 1987, Deckman says. This is because of the need for refiners in coming years to process heavier crudes, containing larger amounts of sulfur and nitrogen. Growth might have been even higher, he says, but for the current oversupply of oil and consequent

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accessibility of lighter crudes. This condition caused many refiners to delay installation of units to treat residual oil, each one of which takes large amounts of catalyst just to fill it for the first time.

Cyanamid is thought to have the largest market share of hydrotreating catalysts, followed by Akzo Chemie America, Shell Chemical, and Katalco. Competition is rife in this market, owing mainly to a yearlong push by Shell Chemical in all its refining catalysts. As catalyst department manager Brian A. Turner tells it, the firm increased its development efforts, capitalizing on technology it had, to bring out new products. Shell Chemical also doubled its catalyst sales force, bringing in people with product development and refinery management experience, who could best show customers how to get results.

Shell Chemical's catalyst department has the advantage of cooperation from its parent's refineries to try out new catalysts. This is important to carry field experience to customer prospects outside Shell. But a catalyst producer need not be owned by an oil company. Engelhard has a close relationship with Atlantic Richfield that allows the firm to get needed refinery operating data, says John R. Gilmore, Engelhard's senior product manager for reforming catalysts.

Both Harshaw and Filtrol were makers of hydrotreating catalysts separately, and some observers say that their combined forces could someday make them a much bigger power there. Others note, however, that neither was ever a very big factor in hydrotreating catalysts, and that together they hold no more than 10% of the market.

Whereas hydrotreating cleans up refinery streams for other processes, hydrocracking converts heavy feeds to high-quality middle distillates for such uses as diesel and jet fuel. Hydrocracking is expensive, however. Catalysts are about $20 per lb, and hydrogen, when not available in sufficient amounts from reforming, must be made by steam reforming of naphtha. Nevertheless, hydrocracking has found roles at refineries.

Cyanamid's McCulloch comments that the hydrocracking process is cost-effective whenever there is a market for the diesel-type output, whose low aromatics content suits it to this use. Turner of Shell Chemical says there is an advantage in the versatility of hydrocracking in accepting heavier feeds.

Though hydrocracking has found its niche at refineries, fluid catalyt-

Catalyst consumption will grow 5% annually

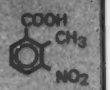
Consumption[a]	1982 Millions of lb	1982 $ Millions (constant)	1987 Millions of lb	1987 $ Millions (constant)
PETROLEUM REFINING	**4377**	**$ 510**	**5113**	**$ 620**
Catalytic cracking	350	235	445	330
Alkylation	4000	150	4635	170
Hydrotreating	21	65	27	85
Hydrocracking	2	40	2	45
Catalytic reforming	4	20	4	20
CHEMICAL PROCESSES	**200**	**465**	**248**	**570**
Polymerization	65	215	83	270
Organic synthesis	90	80	110	95
Oxidation, ammoxidation, and oxychlorination	10	75	12	90
Hydrogen, ammonia, and methanol synthesis	23	50	28	60
Hydrogenation	8	35	10	42
Dehydrogenation	4	10	5	13
EMISSION CONTROL	**na**	**333**	**na**	**297**
Automotive	na	330	na	285
Industrial	na	3	na	12
TOTAL	4577[b]	$1308	5361[b]	$1487

a Includes captive use. b Emission control poundage not included, as figures not compiled. na = not available. Source: Strategic Analysis

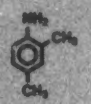
ORGANIC INTERMEDIATES FROM SWITZERLAND

for
- dyestuffs
- pharmaceuticals
- agrochemicals
- perfumes
- flavours
- photochemicals

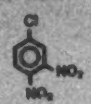
3-Nitro-o-toluic acid
and other isomers



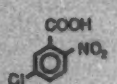
2,4-Xylidine
and all other isomers



1-Chloro-3,4-dinitrobenzene



5-Chloro-2-nitrobenzoic acid
and other isomers



2,3-Dimethyl-6-nitroaniline
6-Nitro-2,3-xylidine

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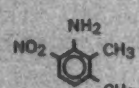
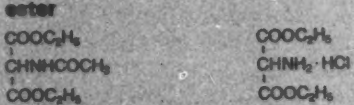


Aminomalonic acid diethyl ester
Acetylaminomalonic acid diethyl ester



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ic cracking (FCC) is still the far more important process, because it converts heavy feeds to lighter product suitable for gasoline. Paul J. Norris, Engelhard's petroleum catalyst marketing director, expects use of FCC catalysts to grow moderately this decade, owing to increased processing of residual oil, countered by current excess U.S. refining capacity. Before building new cracking units, Norris explains, refiners can use their currently idle cracking capacity.

For the future, Norris expects development of FCC catalysts to progress toward specialized types. These specialized types will have unique abilities to solve such problems as refining residual, high-nitrogen, or high-sulfur gas oils, or to resist attrition in crackers.

A shakeup in current FCC market structure is sure to come as a result of the entry of Katalistiks. Company president Regius Lippert claims the firm already has garnered 10% of the U.S. market. Offering a very low price for trial periods, Katalistiks got orders to supply replacement catalyst to half a dozen units. Because catalyst attrition can reach up to 4% per day in units cracking residual oil, as little as 25 days were needed to replace all the catalyst to judge performance of Katalistiks' product alone.

Besides catalytic cracking, reforming is another process used to make gasoline. About 75% of U.S. refining has switched to platinum-rhenium reforming catalysts, estimates Gilmore of Engelhard, because of the longer catalyst life compared to one year for types that were used previously.

Gilmore predicts that penetration will reach 90% in this decade, owing to replacement of old reformers with new ones that operate under more severe conditions. Increasing severity of reforming increases the aromatics content of the reformate needed for high-octane gasoline, but also lowers yield and shortens lifetimes of other catalysts. Gilmore expects demand for reforming catalysts to increase slightly, because of decreased gasoline demand, offset by increasing need to use aromatics content to replace the declining use of lead, as well as increased offerings of unleaded premium gasolines.

In addition to the auto and refining industries, chemical and plastic resin production also requires a large volume of catalysts. Process and therefore catalyst types are much more numerous in making chemicals and resins than in refining. And whereas the platinum-rhenium catalyst is the only recent breakthrough in refining, chemicals and resins depend on continuous quantum jumps in catalyst development. This has been especially true since 1973, when concerns over energy and feedstock shortages triggered a push toward lower process pressures and temperatures, elimination of intermediates, and use of such alternative raw materials as carbon monoxide and hydrogen.

For example, Tennessee Eastman will use rhodium catalysts at its Kingsport, Tenn., acetic anhydride plant, developed by itself and Halcon International, for a series of processes that begin with carbon monoxide and hydrogen from coal gasification. Halcon has invented similar catalysts for vinyl acetate production. Union Carbide also is working on a rhodium catalyst to make ethylene glycol from synthesis gas, bypassing ethylene and ethylene oxide.

Economic feasibility of the Carbide process will depend on what further improvements such companies as Shell Chemical can make in catalysts for direct oxidation of ethylene to ethylene oxide. During the 1970s, Shell and other firms pushed yields past 80% from 70%, thus making direct oxidation increasingly attractive.

Carbide, Dow Chemical, and Du Pont have developed proprietary catalysts to copolymerize ethylene with small amounts of such olefins as 1-butene to produce linear low-density polyethylene. This technology, which produces a superior product and saves on energy and capital investment costs, has since been extended by Carbide to polypropylene. Not to be outdone, Italy's Montedison has perfected a polypropylene catalyst that likewise saves energy and costs of removing catalyst residues and atactic polypropylene. □